

DESCRIPTION

NATURAL RUBBER FREE FROM PROTEINS, AND COMPOSITION AND USE
THEREOF

5

Field of the Invention

The present invention relates to natural rubber free from proteins, and a composition and use thereof. More specifically, it relates to natural rubber which substantially does not
10 contain proteins with specific molecular weight which are characteristic of natural rubber latex, and a composition and use thereof.

Background of the Invention

15 Heretofore, natural rubber has been applied to a wide variety of products ranging from industrial products such as tires for automobiles and aircraft, conveyer belts and adhesives to household products such as gloves. Natural rubber is collected as latex containing water, proteins, inorganic
20 salts and the like in addition to the rubber component and this latex is coagulated to give crude rubber (crepe rubber or smoked sheet rubber). A target rubber product is produced from this crude rubber through mastication, addition of compounding agents, molding, and vulcanization.

25 Fresh latex of natural rubber contains non-rubber components such as proteins, lipids, carbohydrates and inorganic substances in addition to about 30 to 35% w/v (by weight/volume) of rubber component. Solid natural rubber (crude rubber) obtained by coagulating the fresh latex with
30 formic acid contains about 6 wt% of the non-rubber components. These non-rubber components are known to be important for natural rubber to exhibit specific physical properties. However, it has become a social problem around 1990 that some of proteins contained in natural rubber latex products, gloves

in particular, cause Type I acute allergy, and Food and Drug Administration (FDA) in U.S.A. has issued a medical alert toward manufacturers of rubber products to reduce soluble proteins contained in latex products.

5 Following methods are known as a technique for reducing proteins in latex, (i) a method of successive centrifuging the latex, (ii) a method of treating the latex with a proteolytic enzyme, (iii) a method of treating the latex with alkali, and (iv) a method of treating enzymatically deproteinized latex
10 with alkali (refer to JP-A 30301 (2003)). However, even after treatments by these (i), (ii), and (iii) methods, the resulting natural rubber still contains a substantial amount of nitrogenous compounds and they are not able to be free from Type I allergic reactions. Moreover, the methods (ii) and (iv)
15 using a proteolytic enzyme are resulted in the formation of rubber containing residual proteins originated from the enzyme, which can be some allergen. Furthermore, the method (iv) requires troublesome and costing two steps of treatment, i.e., the treatment of the proteolytic enzyme followed by alkali
20 treatment and showed no finding to prove the formation of rubber free from allergy.

As a result of extensive studies on proteins contained in natural rubber latex, the present inventors have found that it is difficult to remove all proteins by ordinary proteolytic
25 enzymes. Because, the proteins in the natural rubber are present in the serum of the latex and on the surfaces of rubber particles in the latex as shown in Fig. 1. The surface of the rubber particles in latex is known to be stabilized by a double-layer comprising of lipids and proteins.

30 Thus, by the method (i) of centrifuging the latex, the proteins in the serum can be removed, but the proteins on the surfaces of the rubber particles cannot be removed. Meanwhile, by the method (ii) of treating the latex with a proteolytic enzyme or the method (iii) of treating the latex with alkali,

although the proteins on the surfaces of the rubber particles can be decomposed, coagulation of the rubber particles occurs during the treatment, so that enzymatic hydrolysis or chemical hydrolysis of the proteins remaining on the rubber particles becomes extremely slow, thereby making it impossible to remove all of the remaining proteins. Moreover, by the method (ii) the presence of residual proteins from the proteolytic enzyme is inevitable.

Under the circumstances, one of the present inventors has made intensive studies. As a result, he has found a method of producing natural rubber containing a reduced amount of nitrogen to 0.02% or less, the content of which is known to be an index of the protein content, and already filed a patent application for the invention (refer to JP-A 56902 (2003)). The method comprises the steps of treating natural rubber latex with a surfactant and a proteolytic enzyme and then concentrating and washing the treated latex once or twice by centrifugation. Since the latex obtained by this method has highly deproteinized, gloves prepared by use of the low-protein natural rubber reduce the possibility for Type I allergic reactions.

However, in this deproteinization method, the addition of about 1% of a surfactant or surfactants makes it difficult to produce solid natural rubber by an ordinary coagulation method. In addition, the method requires a step of removing decomposed proteins by centrifugation. Accordingly, the method is not suitable for mass production of natural rubber. Further, it has been confirmed by a clinical test with a scratch method, which is a more strict testing method, that about 8% of patients are still positive for Type I allergy with respect to the low-protein natural rubber obtained by this method (R. Hayakawa et. al., Environ. Dermatol., 6, 10 (1999)), indicating that deproteinization by this method is not complete.

Detailed Description of the Invention

Problems to be solved by the Invention

Therefore, an object of the present invention is to
5 investigate the substances which cause allergic reactions,
and based on the findings obtained here to provide natural
rubber free from substances determined to be the cause of Type
I allergy.

Another object of the present invention is to provide
10 a rubber composition having good processability and physical
properties by compounding the natural rubber of the present
invention with other rubber.

Still another object of the present invention is to
provide a tire product comprising the above natural rubber
15 of the present invention.

Other objects and advantages of the present invention
will be apparent from the following description.

Brief Description of the Drawings

20 Fig. 1 is a schematic illustration of the distribution
of proteins in natural rubber latex.

Fig. 2 is a diagram showing the results of measurements
of the rubbers obtained in Examples 1 and 2 of the present
invention by SDS-PAGE.

25 Fig. 3 is a diagram showing the result of measurement
of the natural rubber obtained in Comparative Example 1 by
SDS-PAGE.

Fig. 4 is a diagram showing the results of measurements
of the natural rubbers obtained in Examples 3 to 8 of the present
30 invention by SDS-PAGE.

Fig. 5 is a diagram showing the result of measurement
of the natural rubber obtained in Example 9 of the present
invention by SDS-PAGE.

Fig. 6 is a diagram showing comparisons of the green

strength of the natural rubbers (Examples 15 and 16) of the present invention, natural rubber (Comparative Example 6) and deproteinized natural rubber by enzymatic deproteinization.

5 Means for Solving the Problems

According to the present invention, firstly, the above objects and advantages of the present invention are achieved by natural rubber which contains substantially no proteins specified by the bands of 14, 31 and 45 kDa by an SDS-PAGE
10 method.

Further, according to the present invention, secondly, the above objects and advantages of the present invention are achieved by a rubber composition comprising the above natural rubber of the present invention and other rubber.

15 Finally, according to the present invention, thirdly, the above objects and advantages of the present invention are achieved by tires produced by use of the above natural rubber of the present invention.

20 Best Mode for Embodiments of the Invention

Hereinafter, the present invention will be further described. Firstly, a description will be given to a method for producing the natural rubber of the present invention.

The method for producing the natural rubber of the present
25 invention is carried out by saponifying natural rubber latex with an alkali hydroxide in the presence of an anionic surfactant or nonionic surfactant, coagulating the saponified latex, and then washing the coagulated rubber with an aqueous solution of an alkali hydroxide or a surfactant as required.

30 When the natural rubber latex is saponified with the alkali hydroxide, coagulation of the latex can be prevented by use of the anionic surfactant or nonionic surfactant as described above. That is, although an anionic surfactant, a cationic surfactant and a nonionic surfactant are known as

surfactants, a nonionic surfactant and/or an anionic surfactant must be used in this case.

Illustrative examples of usable nonionic surfactants include polyoxyalkylene ether nonionic surfactants, 5 polyoxyalkylene ester nonionic surfactants, polyhydric alcohol fatty acid ester nonionic surfactants, sugar fatty acid ester nonionic surfactants and alkylpolyglycoside nonionic surfactants. Specific examples of the polyoxyalkylene ether nonionic surfactants include a 10 polyoxyalkylene alkyl ether, a polyoxyalkylene alkyl phenyl ether, a polyoxyalkylene polyol alkylene ether, a polyoxyalkylene styrenated phenol ether, a polyoxyalkylene distyrenated phenol ether, and a polyoxyalkylene tristyrenated phenol ether.

15 The polyoxyalkylene polyol of the above polyoxyalkylene polyol alkylene ether may be a polyhydric alcohol having 2 to 12 carbon atoms. Illustrative examples thereof include propylene glycol, glycerin, sorbitol, sucrose, pentaerythritol, and sorbitan.

20 Illustrative examples of the polyoxyalkylene ester nonionic surfactants include a polyoxyalkylene fatty acid ester.

Illustrative examples of the polyhydric alcohol fatty acid ester nonionic surfactants include a fatty acid ester 25 of a polyhydric alcohol having 2 to 12 carbon atoms and a fatty acid ester of a polyoxyalkylene polyhydric alcohol. Specific examples thereof include sorbitol fatty acid ester, sorbitan fatty acid ester, fatty acid monoglyceride, fatty acid diglyceride, and a polyglycerin fatty acid ester. Further, 30 their polyalkylene oxide adducts (such as a polyoxyalkylene sorbitan fatty acid ester and a polyoxyalkylene glycerin fatty acid ester) can also be used.

Illustrative examples of the sugar fatty acid ester nonionic surfactants include fatty acid esters of sucrose,

glucose, maltose, fructose and polysaccharides. Their polyalkylene oxide adducts can also be used.

Illustrative examples of the alkylpolyglycoside nonionic surfactants include an alkylglucoside, an
5 alkylpolyglucoside, a polyoxyalkylene alkylglucoside and a polyoxyalkylene alkylpolyglucoside. Further, their polyalkylene oxide adducts can also be used.

Preferred examples of the fatty acids of the above polyhydric alcohol fatty acid ester and sugar fatty acid ester
10 surfactants are a linear or branched saturated or unsaturated fatty acid having 4 to 30 carbon atoms.

The alkyl group in the surfactant is exemplified by an alkyl group having 4 to 30 carbon atoms. Further, the polyoxyalkylene group is exemplified by one having an alkylene
15 group having 2 to 4 carbon atoms, more specifically, one with about 1 to 50 added moles of ethylene oxide.

Illustrative examples of the anionic surfactant include carboxylic acid based anionic surfactants, sulfonic acid based anionic surfactants, sulfuric ester anionic surfactants and
20 phosphoric ester anionic surfactants.

Illustrative examples of the carboxylic acid based surfactants include a fatty acid salt, polyvalent carboxylate, rosinate and tall oil fatty acid salt which have 6 to 30 carbon atoms. A carboxylate having 10 to 20 carbon atoms is preferred.
25 When the number of carbon atoms is 6 or less, dispersion and emulsification of proteins and impurities are insufficient, while when the number of carbon atoms is 30 or more, the surfactant becomes difficult to be dispersed in water.

Illustrative examples of the sulfonic acid based
30 surfactants include an alkyl benzene sulfonate, an alkyl sulfonate, an alkyl naphthalene sulfonate, naphthalene sulfonate and diphenylether sulfonate.

Illustrative examples of the sulfuric ester surfactants include an alkyl sulfate, a polyoxyalkylene alkyl sulfate,

a polyoxyalkylene alkyl phenyl ether sulfate, tristyrenated phenol sulfate and a polyoxyalkylene distyrenated phenol sulfate. Illustrative examples of the salts of these compounds include metal salts (such as Na, K, Ca, Mg and Zn), ammonia salts and amine salts (such as a triethanolamine salt).

Illustrative examples of the phosphoric ester surfactants include an alkyl phosphate and a polyoxyalkylene phosphate. Illustrative examples of the salts of these compounds include metal salts (such as Na, K, Ca, Mg and Zn), ammonia salts and amine salts (such as a triethanolamine salt).

The above described surfactant is preferably added in an amount of 0.01 to 0.7% (w/v), more preferably 0.03 to 0.5%, particularly preferably 0.05 to 0.3%, based on the rubber latex. When the amount is smaller than the lower limit, the effect of the surfactant is not sufficient, while when the amount is larger than the upper limit, the coagulation reaction of the rubber latex after the saponification reaction is liable to become difficult to occur.

The conventional method which has already been filed as a patent application and proposed by one of the present inventors, i.e., the method of producing natural rubber having the nitrogen content of 0.02% or less by treating natural rubber latex with a surfactant and a proteolytic enzyme must use the surfactant in an amount of at least about 1%. Accordingly, it is one of advantages of the method of the present invention that natural rubber having low protein content can be produced by use of a less amount of surfactant as described above. It is also one of reasons why the method of the present invention is suitable for mass production.

Further, the method of the present invention is also excellent in that it can produce natural rubber leaving intact fatty acids which are known to play an important role to express physical properties peculiar to the natural rubber.

Further, as the alkali hydroxide for saponifying the

natural rubber latex, sodium hydroxide or potassium hydroxide is preferably used, for example. The amount of the alkali hydroxide is preferably 1 to 10% (w/v) based on the rubber latex. When the amount is smaller than 1%, the reaction time becomes too long, while when the amount is larger than 10%, the coagulation reaction is liable to occur. A more preferred amount is 1 to 8%. When the amount of the alkali hydroxide is too large, a large portion of the lipids becomes liable to be saponified and removed. It is preferable that the alkali hydroxide as 10 to 30 wt% aqueous solution is added to the natural rubber latex.

The natural rubber latex saponified with the alkali hydroxide and the surfactant may be fresh natural rubber latex or high ammonia latex.

Although the reaction time is not particularly limited, the reaction is preferably carried out from several minutes to about one day. Further, during the reaction, the latex may be agitated or left to stand. However, the latex is preferably agitated so as to accelerate the reaction. In addition, the temperature may be adjusted as required, and a suitable temperature is 5 to 90°C, more preferably 20 to 70°C.

In the method of the present invention, after saponification, a coagulant is added so as to coagulate the rubber latex.

As the coagulant, a combination of polymer flocculant and acid, a combination of salt and acid, and/or a combination of all of these are/is preferably used.

Illustrative examples of the polymer flocculant include anionic, cationic and nonionic polymer flocculants. The anionic and cationic polymer flocculants are preferred. Specific examples of the anionic polymer flocculants include a poly(sodium acrylate), a poly(ammonium acrylate) and a poly(sodium styrene sulfonate). Specific examples of the cationic polymer flocculants include a poly(ethylene amine),

a poly(2-hydroxypropyl-N-methylammoniumchloride), a poly(2-hydroxypropyl-1,1-N-dimethylammoniumchloride), a poly[N-(dimethylaminomethyl)acrylamide], a poly(2-vinylimidazoliniumbisulfate), a
5 poly(diallyldimethylammoniumchloride), a poly(N,N-dimethylaminoethylmethacrylate) and a poly[N-(dimethylaminopropyl)methacrylamide].

Further, as the salt, a variety of inorganic salts can be used. Preferred examples thereof include sodium chloride,
10 ammonium phosphate, ammonium sulfate and calcium nitrate. As the acid, a variety of inorganic acids and organic acids are used. However, sulfuric acid, formic acid, acetic acid and the like are preferably used from a practical standpoint.

The coagulated latex is then subjected to solid-liquid
15 separation by means known per se. After the separation, the resulting rubber may be washed with an aqueous solution of an alkali hydroxide and/or a surfactant or immersed in an aqueous solution of an alkali hydroxide and/or a surfactant as required so as to further reduce nitrogen contained in the rubber or
20 lessen color peculiar to the natural rubber latex.

A series of these reactions can be carried out in a batch or continuous manner. In the continuous manner, an alkali hydroxide and a surfactant are continuously added in natural rubber latex, and after completion of the saponification
25 reaction, by use of, for example, a line mixer, a coagulant is continuously added so as to coagulate the saponified latex continuously. Thereby, a method of producing natural rubber continuously, which has heretofore been impossible, can be adopted. Thus, the method of the present invention is a
30 remarkable and excellent method capable of mass-producing natural rubber at low cost.

The natural rubber with a reduced nitrogen content which is produced by the above method of the present invention is characterized in that it contains substantially no proteins

specified by the bands of 14, 31 and 45 kDa as analyzed by SDS-PAGE (SDS-Polyacrylamide Gel Electrophoresis) with a molecular weight calibration curve by using standard molecular weight markers. In this regard, the natural rubber is different
5 from the conventionally known natural rubber with reduced nitrogen content.

The natural rubber of the present invention may have the nitrogen content of 0.02 to 0.30% by weight. Furthermore, the natural rubber of the present invention contains substantially
10 no proteolytic enzyme and its decomposed compounds.

That is, it has been confirmed with analysis by SDS-PAGE that the natural rubber having reduced nitrogen content of 0.02% or less which has been produced by the conventional method, using a surfactant and a proteolytic enzyme, still shows these
15 bands indicating the presence of residual specific proteins. More specifically, when the natural rubber of the present invention is compared with the natural rubber obtained by the above conventional method on the same level of nitrogen content, it has been found that as analyzed by SDS-PAGE, the bands of
20 14, 31 and 45 kDa substantially or completely disappeared from the natural rubber of the present invention, while the above bands, though in very small amounts, are still present in the natural rubber obtained by the above conventional method. Further, when the natural rubber latex treated by the above
25 conventional method is subjected to centrifugation, the bands of proteins peculiar to natural rubber latex are clearly found in its serum phase, ensuring that undecomposed proteins remain in the latex. Meanwhile, when the natural rubber latex treated by the method of the present invention is subjected to
30 centrifugation, no such bands are found in its serum phase. Hence, it is easily confirmed that the coagulated natural rubber latex after the reactions is free from these proteins.

Further, it has been found that the proteins specified by the bands of 14, 31 and 45 kDa by SDS-PAGE are substances

to cause Type I allergy, and based on this fact, it has been found by studies of the present invention that natural rubber which is substantially free from the bands of 14, 31 and 45 kDa when analyzed by SDS-PAGE can provide rubber products such
5 as a glove which can be used safely on patients having Type I allergy with no problem even if the natural rubber contains a slightly large amount of nitrogen.

It has also been found that the reason why the natural rubber of the present invention as described above is different
10 from the conventional natural rubber, i.e., the nitrogen content of the natural rubber resulting from deproteinization using a proteolytic enzyme is reduced by selective cuttings of some of the amide bonds in the proteins by the proteolytic enzyme, while saponification using an alkali hydroxide
15 according to the present invention hydrolyzes the amide bonds in the proteins unselectively and stoichiometrically, thereby achieving a low molecular weight. Therefore, the natural rubber of the present invention is characterized in that it is not limited by the content of remaining nitrogen and contains
20 substantially no proteins peculiar to natural rubber latex and proteolytic enzyme.

Further, the natural rubber of the present invention has lower green strength than the conventional natural rubber. The conventional natural rubber specimen from latex has a green
25 strength of about 8 to 10 MPa and the specimen from the natural rubber latex deproteinized by the enzyme method has a green strength of about 4 to 6 MPa, whereas the natural rubber of the present invention has a green strength of about 0.1 to 3 MPa.

30 For this reason, a mastication process using a Banbury mixer or the like which is essential in processing of the conventional natural rubber can be omitted depending on products, which is very advantageous from the viewpoint of energy conservation.

The physical properties of the vulcanized natural rubber of the present invention are no different from those of the conventional natural rubber, and compositions comprising the natural rubber of the present invention and various synthetic rubbers also show excellent vulcanized rubber properties. As the synthetic rubbers, all rubbers which can be blended with the conventional natural rubber, can be used. Illustrative examples thereof include SBR, NBR, BR, IR, EPR, EPDM and IIR. It has been confirmed that the vulcanization physical properties of rubber compositions comprising the natural rubber of the present invention and these synthetic rubbers are comparable to or better than those of rubber compositions comprising the conventional natural rubber and these synthetic rubbers and that the saponification according to the present invention does not affect the vulcanized rubber properties of the rubber compositions.

Due to the foregoing excellent physical properties, natural rubber obtained by saponification according to the present invention is very useful for such applications as tires and other natural rubber products.

Hereinafter, the present invention will be described in more detail with reference to Examples. However, the present invention shall not be limited by these Examples in any way.

Examples

Example 1

To 1.9 L of fresh latex (abbreviated as FL-latex) adjusted to a DRC (Dry Rubber Content) of 30%, aqueous solution of NaOH containing 30 g of NaOH in 100 mL water and 4 g of Triton X-100 (isooctylphenoxypoly-ethoxyethanol, BDH Laboratories Suppliers, Co.) as a nonionic surfactant were added, and the saponification reaction was carried out at 70°C for 3 hours. To the resulting latex, 300 mL of 0.025% (w/v) Floerger as an anionic polymer flocculant was added. Then, 1.5 L of 5%

(w/v) formic acid was added so as to coagulate the rubber, which was then washed with water and dried at 50°C for 2 days. The obtained saponified natural rubber (abbreviated as SAP-NR-1) had the nitrogen content of 0.133%. About 5 g of this rubber was pressed into a sheet having a size of 5 cm X 5 cm and a thickness of 0.2 to 0.3 mm. This coagulated rubber was cut into a slit (2 mm X 10 mm X 1 mm) and then extracted twice by use of 2% (w/v) aqueous SDS (Sodium Dodecyl Sulfate) 10 mL with stirring at room temperature for 24 hours. The extract was dialyzed by use of a membrane having a cutoff molecular weight of 3.5 kDa for 24 hours. To 300 µL of this solution, 100 µL of acetone containing 10% trichloroacetic acid was added to precipitate the proteins. The precipitate was collected by centrifugation, washed with acetone, and then dissolved in 50 µL of 8 M urea aqueous solution so as to obtain an extract corresponding to sixfold concentration. This extract was measured by use of SDS-PAGE (Polyacrylamide Gel Electrophoresis).

The result of the measurement by SDS-PAGE of the extract is shown in Fig. 2. In Fig. 2, Lane 1 denotes standard molecular weight markers, Lane 2 corresponds to Example 1 (SAP-NR-1), Lane 3 corresponds to Example 2 (SAP-NR-1-1), and Lane 4 denotes the extract from serum of fresh latex.

In this measurement, SAP-NR-1 showed no bands peculiar to the proteins in the rubber. It was revealed that SAP-NR-1 contained no proteins showing the bands of 14, 31 and 45 kDa by SDS-PAGE despite the nitrogen content of 0.133%.

For comparison, the result of measurement by SDS-PAGE of the serum extract of fresh latex under the same conditions is also shown in Fig. 2. The bands of 14, 31 and 45 kDa can be clearly recognized.

Example 2

After saponification and coagulation in the same manner

as in Example 1, the resulting natural rubber was immersed in a 3% (w/v) NaOH aqueous solution at 70° C for 1.5 hours followed by washing with water and drying under the same conditions as used in Example 1. The nitrogen content of the obtained
5 rubber (SAP-NR-1-1) was very low at 0.025%. The result of SDS-PAGE analysis made under the same conditions as used in Example 1 is shown in Fig. 2. As it is expected in this case as well, it was revealed that the rubber contained no protein showing bands of 14, 31 and 45 kDa as measured by SDS-PAGE.

10

Comparative Example 1

To 2L of fresh latex with a DRC of 10%, 20 g of SDS and 0.8 g of Alcalase 2.0T (NOVO Nordisk Bioindustry Co.) as a proteolytic enzyme were added, and the reaction was carried
15 out at room temperature for 24 hours. The reacted latex was concentrated to a DRC of 60% by centrifugation at 15,000 rpm for 30 minutes. The concentrated latex was diluted to 10% DRC and concentrated to 60% DRC again by centrifugation in a similar way mentioned above.

20 The nitrogen content of the resulting deproteinized natural rubber coagulated by acetone was 0.018%. This coagulated rubber was cut into a slit, which was then measured by SDS-PAGE in the same manner as in Example 1. The result is shown in Fig. 3. In Fig. 3, Lane 1 denotes standard molecular
25 weight markers, and Lane 2 corresponds to Comparative Example 1. The presence of the bands of 31 and 45 kDa as well as a broad band around 21 kDa was seen in Lane 2.

Examples 3 to 8

30 Experiments were conducted under the same conditions as used in Example 1. The conditions for saponification are shown in Table 1.

Table 1

	Conditions for Saponification	Nitrogen Content of Obtained Rubber: (w/w%)
Ex. 3	NaOH 1% / Room Temperature / 1 Hour	0.336
Ex. 4	NaOH 1% / 70° C / 1 Hour	0.133
Ex. 5	NaOH 2% / Room Temperature / 5 Hours	0.147
Ex. 6	NaOH 2% / Room Temperature / 25 Hours	0.080
Ex. 7	NaOH 3% / 70° C / 1 Hour	0.100
Ex. 8	NaOH 3% / 70° C / 5 Hours	0.119

Ex. = Example

Note: The conditions for saponification indicate the
5 concentration of NaOH, reaction temperature, and reaction time.

The results of measurements made on the obtained rubbers by SDS-PAGE under the same conditions as used in Example 1 are shown in Fig. 4. In Fig. 4, Lane 1 denotes standard molecular weight markers, and Lanes 2 to 7 corresponds to Examples 3 to 8, respectively. According to the results of the measurements by SDS-PAGE, under the conditions (NaOH 1% (w/v), room temperature, 1 hour) of Example 3, a protein band of around 14 kDa somewhat appeared (Lane 2), although the bands of 31 and 45 were nearly absent. Under the conditions of Examples 4 to 8, the bands of 14, 31 and 45 did not appear at all, indicating that proteins were removed completely under these saponification conditions.

20 Example 9

The coagulated natural rubber after saponification (before drying in Example 3) obtained in Example 3 was further immersed in a 2% (w/v) NaOH aqueous solution at room temperature for 1 day, washed with water and dried, and then subjected to an SDS-PAGE test. The result is shown in Fig. 5. In Fig. 5, Lane 1 denotes standard molecular weight markers, and Lane

2 is the result of Example 9. It is clear that the specific protein bands completely disappeared by the above treatment.

Examples 10 to 12

- 5 The procedure of Example 1 was repeated except that compounds shown in Table 2 were used as surfactants in place of Triton-X100. As a result, it was found that none of the rubbers of Examples 10 to 12 contained proteins specified by the bands of 14, 31 and 45 kDa as measured by SDS-PAGE.

10

Table 2

	Surfactants	Amount (Based on Rubber, 100prt)	Nitrogen Content (%)	Proteins (kDa) 14, 31, 45
Ex. 10	Polyoxyethylene Lauryl Ether	0.3	0.145	Not Exist
Ex. 11	Polyoxyethylene Oleyl Ether	0.3	0.168	Not Exist
Ex. 12	Sodium Dodecyl benzene Sulfonate	0.4	0.173	Not Exist

Ex. = Example

Examples 13 and 14 and Comparative Examples 2 to 4

- 15 Allergy tests of saponified natural rubber and deproteinized natural rubbers were conducted. It was checked whether trace amounts of nitrogenous compounds present in the rubbers contained Type I acute allergy antigens.

For comparison, deproteinized natural rubbers (DPNR) by the use of a proteolytic enzyme were tested under the same conditions.

The experiments were conducted by the analysis of proteins with enzyme-linked immunosorbent assay (ELISA) using FIT Kit of FIT BIOTECK CO., LTD. The results are shown in Table 3.

25

Table 3

	Amount of Protein by ELISA ($\mu\text{g/ml}$)					N (%)
	Hev b1	Hev b3	Hev b5	Hev b6.02	Total	
Ex. 13	ND	ND	ND	ND	ND	0.133
Ex. 14	ND	ND	ND	ND	ND	0.035
C.Ex.2	203	104	13	247	567	0.721
C.Ex.3	ND	ND	ND	14	14	0.177
C.Ex.4	ND	ND	ND	1.5	1.5	0.035

Ex. = Example, C.Ex. = Comparative Example

(Hev b1: MW 14.6 kDa, Hev b3: MW 22.3 kDa, Hev b5: MW 17.5 kDa and Hev b6.02: MW 4.7 kDa are proteins referred to as Rubber elongation factor, Small rubber particle protein, Acidic latex protein and Mature Hevein, respectively.)

The samples were prepared in the following manner.

For Example 13, a sample prepared by saponifying fresh rubber latex with 1% (w/v) NaOH at 70°C for 1 hour was used and the resulting rubber was post-treated under the same conditions as used in Example 1. For Example 14, a sample prepared by immersing the rubber of Example 13 in a 2% (w/v) NaOH aqueous solution at room temperature for 1 day was used. For Comparative Example 2, a sample prepared by coagulating fresh natural rubber latex was used. For Comparative Example 3, a sample prepared by treating fresh latex with the proteolytic enzyme Alcalase 2.0T (NOVO Nordisk Bioindustry Co.) followed by coagulation of the resulting latex was used. For Comparative Example 4, a sample deproteinized by use of the proteolytic enzyme as in the case of Comparative Example 3, followed by centrifuging the resulting sample twice and then coagulating the latex was used.

The results are as follows. That is, proteins were detected from Comparative Examples 2, 3 and 4, and no protein was detected from Examples 13 and 14. Thus, it was confirmed that the natural rubbers deproteinized by saponification were free from the possibility of causing allergy.

Examples 15 and 16 and Comparative Examples 5 and 6

For Example 15, a sample latex was obtained by adding aqueous solution of NaOH containing 30 g of NaOH in 100 mL water and 4 g of Triton X-100 as a nonionic surfactant to 2L of fresh latex with a DRC of 30% so as to saponify the latex at 70°C for 3 hours. The obtained latex was poured onto a glass plate and dried at 50°C for 1 day so as to obtain a film. After rinsed with water, an antioxidant was added to the film by a method of immersing the film in a 1% (w/v) aqueous emulsion of BHT. Example 16 was obtained by immersing the film of Example 15 in a 2% (w/v) NaOH aqueous solution at room temperature for 1 day. The film was also immersed in the aqueous emulsion of BHT so as to add the antioxidant to the film.

For Comparative Example 5, a sample latex was prepared by use of a commercially available solid natural rubber having a Mooney viscosity of 60, and for Comparative Example 6, a sample latex was prepared by use of natural rubber obtained by coagulating fresh natural rubber latex with Floerger and formic acid as coagulant.

The physical properties of unvulcanized and vulcanized rubbers were measured by use of Rubber Process Analyzer RPA2000 (Alpha Technology Co) (RPA). The conditions for mixing and vulcanization of the rubbers are as shown below. The rubbers and rubber chemicals were mixed together at 50°C for 13 minutes by use of a 0.5 L internal mixer. After the obtained rubber compounds were passed through 2-inch rollers twice, they were kept in the dark at room temperature for 24 hours until vulcanization. They were vulcanized at 155°C by use of the following compounding recipe (Table 4). The physical properties of vulcanizates are shown in Table 5.

Table 4

Recipe	With Carbon Black (CB)	Without Carbon Black (CB)
Rubber	100	100
CB	35	-
Sulfur	2	2
Stearic Acid	3	3
ZnO	5	5
MBT	1	1
Antioxidant (6PPD)	2	2

Numeric values: phr

Note) MBT: 2-mercaptobenzothiazole (vulcanization accelerator)

6PPD: N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine

5

Table 5

	C.Ex.5	C.Ex.6	Ex. 15	Ex. 16
With CB				
Scorch Time (t ₂)	2.09	1.40	1.23	1.13
Cure time (t ₉₀)	7.30	6.07	5.37	4.48
T _b	21.9	23.8	21.3	24.3
E _b (%)	580	540	530	540
M 100 (MPa)	1.30	1.43	1.40	1.43
M 300 (MPa)	5.32	7.30	7.11	7.13
M 500 (MPa)	15.2	18.6	18.6	20.5
Without CB				
Scorch Time (t ₂)	3.04	1.35	1.20	1.05
Cure time (t ₉₀)	7.27	5.09	5.09	4.24
T _b	16.0	15.1	8.78	14.3
E _b (%)	830	800	680	760
M 100 (MPa)	0.50	0.52	0.53	0.56
M 300 (MPa)	1.02	1.12	1.14	1.28
M 500 (MPa)	2.03	2.34	2.78	2.44

Ex. = Example, C.Ex. = Comparative Example

Further, the green strength of the saponified natural rubbers is shown in Fig. 6. The green strength decreased in the order of Comparative Example 6 > DPNR > Example 15 > Example 16. The green strength of the saponified natural rubbers is much smaller than those of natural rubber (FNR) and natural rubber deproteinized by use of the proteolytic enzyme (DPNR).

15

Example 17

The properties of vulcanized products from blended rubbers of saponified natural rubbers with emulsion SBR are shown.

The saponified natural rubbers were prepared in the following manner. Into 1.9L of flesh natural rubber latex (FL-latex), 100mL of aqueous solution containing 4g of nonionic surfactant Toriton X-100 and 30g of NaOH were added. The mixture
5 was reacted at 70° C for 3 hours so as to saponify the latex. The resulting latex was coagulated with a polymer flocculant, Floerger, and formic acid and then rinsed with water.

The obtained rubber was immersed in BHT (an antioxidant: Butylated hydroxy toluene) aqueous emulsion dispersed at a
10 concentration of 1% (w/v) in aqueous solution of 0.5% (w/v) SDS at 50° C for 24 hours. The sample was dried at 50° C for 24 hours (Sample SAP-H).

The SAP-H obtained thus was further immersed in a 2% (w/v) NaOH aqueous solution at room temperature for 24 hours, rinsed
15 with water and then treated in the same manner as SAP-H so as to prepare a sample (SAP-L) having a reduced nitrogen content.

The nitrogen content of SAP-H and SAP-L was 0.110% and 0.094%, respectively. Further, it was confirmed that both samples contained no protein showing the bands of 14, 31 and
20 45 kDa as measured by SDS-PAGE.

Both samples were blended with SBR1502 according to the compounding recipe (recipe for tire carcass) in the following Table 6 so as to prepare vulcanized compositions. The vulcanized physical properties thereof were measured.

Table 6

NR	50 phr
SBR1502	70 phr
CBN660	43 phr
Aromatic Oil	8 phr
ZnO	4 phr
Stearic Acid	1.5 phr
TMQ	1.5 phr
MBT	0.5 phr
TMTD	1 phr
Sulfur	2.5 phr

TMQ: Polymerized 2,2,4-trimethyl-dihydroquinone
(antioxidant)

MBT: 2-mercaptobenzothiazole (vulcanization accelerator)

- 5 TMTD: tetramethylthiuramdisulfide (vulcanization
accelerator)

Mixing was carried out by use of a small-sized mill, and
vulcanization was carried out in the form of a sheet having
10 a thickness of 1 mm. The vulcanization temperature was 155° C,
and the vulcanization time was changed in accordance with the
vulcanization time measured by RPA.

The properties of the vulcanized compositions are shown
in the following Table 7.

15

Table 7

	FNR	SAP-H	SAP-L
Scorch Time	1.50	1.45	1.40
Cure Time	3.42	3.30	3.14
Tb (MPa)	12.59	11.49	11.87
Eb (%)	338	323	331
100M (MPa)	2.58	2.38	2.41
300M (MPa)	9.86	8.42	10.41

The following Table 8 shows the dynamic properties and
abrasion resistances of the vulcanized compositions.

20

Table 8

	FNR	SAP-H	SAP-L
Storage Modulus E' (MPa)	5.172	5.080	5.069
Loss of Modulus E" (MPa)	0.162	0.152	0.153
Tan δ	0.031	0.030	0.030
Heat Build Up ($^{\circ}$ C)	8.0	9.5	9.0
Dynamic Compression Set (%)	2.7	0.8	0
Abrasion (cm ³)	0.100	0.098	0.106

In Tables 7 and 8, FNR represents rubber obtained by coagulating fresh natural rubber latex with acetone. Both SAP-H and SAP-L showed vulcanization physical properties, dynamic properties and abrasion resistances comparable to those of the natural rubber and SBR vulcanized composition.